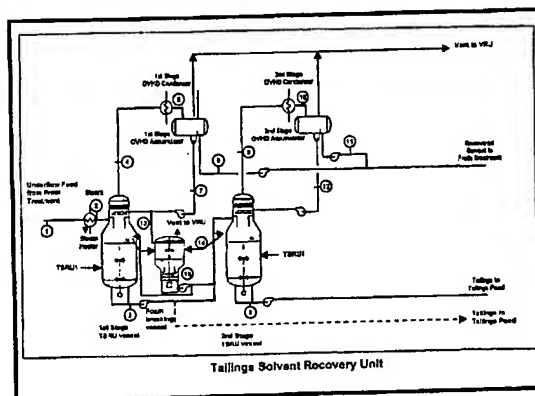(54) METHODE D'ELIMINATION DE SOLVANT PRESENT DANS LE CIRCUIT DE SOUS-ECOULEMENT PROVENANT DE LA DERNIERE ETAPE DE SEPARATION D'UN PROCEDE DE TRAITEMENT PAR MOUSSAGE DES SABLES BITUMINEUX

(54) PROCESS FOR REMOVING SOLVENT FROM AN UNDERFLOW STREAM FROM THE LAST SEPARATION STEP IN AN OIL SANDS FROTH TREATMENT PROCESS

(57)
A process is described for treating an underflow stream containing water, solvent, asphaltenes and solids, from one of the last separation steps in a paraffinic solvent process for separating bitumen from an oil sands froth, wherein a) the stream is introduced to a solvent recovery vessel that is substantially free of internals wherein the temperature and pressure are such that the solvent is normally a vapour, b) a pool of liquid and solids is maintained in the lower part of the vessel at a controlled level for sufficient time to allow the solvent to vapourize, c) the pool is agitated to the point where the asphaltenes are dispersed, submerged and prevented from re-agglomerating and the solids are maintained in suspension, d) the solvent is recovered as an overhead vapour stream, and e) the solvent depleted remainder of the stream is removed from the bottom of the vessel as a liquid slurry.

Tailings Solvent Recovery Unit

(54) Titre : METHODE D'ELIMINATION DE SOLVANT PRESENT DANS LE CIRCUIT DE SOUS-ECOULEMENT PROVENANT DE LA DERNIERE ETAPE DE SEPARATION D'UN PROCEDE DE TRAITEMENT PAR MOUSSAGE DES SABLES BITUMINEUX
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Tailings Solvent Recovery Unit
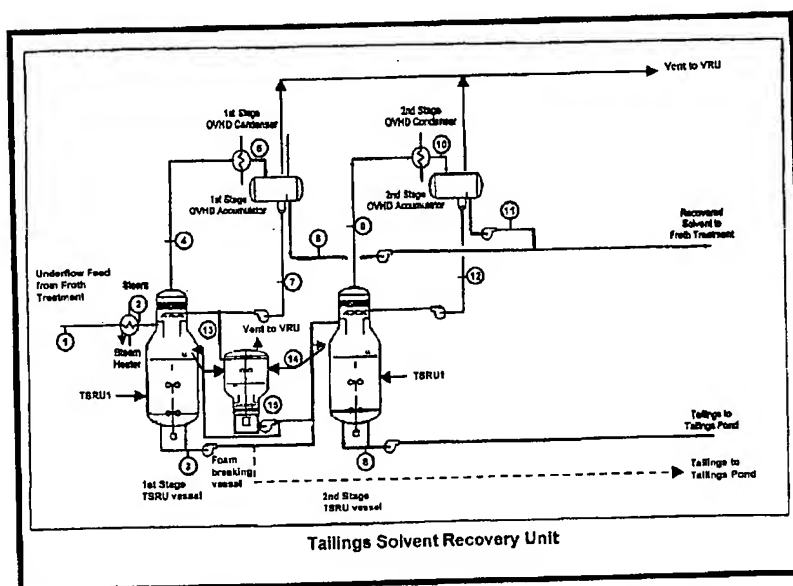
(57) Abrégé/Abstract:
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PROCESS FOR REMOVING SOLVENT FROM AN UNDERFLOW STREAM FROM THE LAST SEPARATION STEP IN AN OIL SANDS FROTH TREATMENT PROCESS

ABSTRACT:

A process is described for treating an underflow stream containing water, solvent, asphaltenes and solids, from one of the last separation steps in a paraffinic solvent process for separating bitumen from an oil sands froth, wherein

    a)   the stream is introduced to a solvent recovery vessel that is substantially free of internals wherein the temperature and pressure are such that the solvent is normally a vapour,

    b)   a pool of liquid and solids is maintained in the lower part of the vessel at a controlled level for sufficient time to allow the solvent to vapourize,

    c)   the pool is agitated to the point where the asphaltenes are dispersed, submerged and prevented from re-agglomerating and the solids are maintained in suspension,

    d)   the solvent is recovered as an overhead vapour stream, and

    e)   the solvent depleted remainder of the stream is removed from the bottom of the vessel as a liquid slurry.

PROCESS FOR REMOVING SOLVENT FROM AN UNDERFLOW STREAM FROM THE LAST SEPARATION STEP IN AN OIL SANDS FROTH TREATMENT PROCESS

BACKGROUND OF INVENTION:

Various methods have been described in prior art water extraction processes for the separation of bitumen from mined oil sands. Typically, cool to hot water is used with or without process additives, such as caustic, to form an oil sands froth. Various techniques have been described to recover bitumen from the oil sands froth, including Canadian patent 2,232,929, which employs a paraffinic solvent in the froth treatment process. In this instance, the process produces an underflow stream consisting primarily of water, solvent, asphaltenes and solids and normally including sand, fine silt/clays and unrecovered heavy hydrocarbons such as bitumen.

Recovery of solvent from the tailings stream is desirable from an economic as well as environmental perspective. Following treatment to recover the solvent, the tailings stream is discharged to tailings ponds.

In the case of paraffinic oil sands froth treatment, separation of fine solids, clays and water droplets is aided by the precipitation of asphaltene solids, leaving a clean hydrocarbon phase and an underflow stream as described above. The presence of asphaltenes in the underflow stream makes this stream difficult to further process for the purpose of recovering the solvent.

SUMMARY OF INVENTION:

In accordance with the invention a process for treating an underflow stream, containing water, solvent, asphaltenes and solids, from the last separation step in a paraffinic solvent process for separating bitumen from an oil sands froth includes the following steps:

a) the stream is introduced to a solvent recovery vessel that is substantially free of internals wherein the temperature and pressure are such that the solvent is normally a vapour,

b) a pool of liquid and solids is maintained in the lower part of the vessel at a controlled level for sufficient time to allow the solvent to vaporize,

c) the pool is agitated to a level of agitation where the asphaltenes are dispersed, submerged and re-agglomeration of asphaltenes is inhibited and the solids are maintained in suspension,

d) the solvent is recovered as an overhead vapor stream, and

e) the solvent depleted remainder of the stream is removed from the bottom of the vessel as a liquid slurry.

Preferably, the pool is agitated with a mechanical impeller of which the impeller configuration, location in the liquid pool, and rotational speed are selected to promote that floating solvent laden asphaltenes are drawn under the liquid surface and to prevent re-agglomeration of the asphaltenes and to promote asphaltene particle size reduction.

The composition of the underflow stream may vary significantly due to changes in composition of the oil sands ore feed to the extraction plant and in the settling process used to isolate the underflow stream. Segregation or partial segregation of components in the underflow stream occurs as this material separates from the dilute bitumen product and settles to the bottom of the vessels designed for this purpose. Typically, the composition of this underflow stream will be about 40-60 w% water; about 15-35 w% mineral solids (sand, clay); about 5-15 w% entrained solvent and about 10-15 w%

asphaltenes and unrecovered bitumen, although wider compositional swings may be encountered as noted.

In addition to the fouling or plugging concerns, certain compositions may be processed that have a high foaming tendency. The foam arises as solvent is vapourized and fine inorganic solids and/or organic solids (such as precipitated asphaltenes) and/or natural surfactants arising from the bitumen stabilize the resulting foam bubbles.

Conventional solvent recovery technology employs vessels with internals such as trays, packing and baffles. Among other things, the internals provide the residence time required for the necessary solvent vapourization to take place. Vessels with such internals are not practical for an underflow stream having the current composition. The conventional approach is unworkable because of the accumulation of inorganic and organic solids and the fouling or plugging of vessel internals, lines and valves. In the current invention the necessary residence time is achieved by having a liquid pool form in the lower part of the vessel.

According to the current invention, solvent is recovered without fouling and plugging by using vessels in which the internals have been removed or modified to prevent fouling and plugging. The vessel(s) are operated at temperatures, pressures and residence times necessary to achieve target solvent recovery levels.

The underflow stream is heated directly by mixing with steam or indirectly by any heat exchanger means that avoids fouling or plugging, to achieve the desired temperature. The heated stream is introduced into the solvent recovery vessel above an agitated liquid pool having sufficient temperature and residence time to achieve a desired level of solvent removal.

Various inlet devices, vessel internal adaptations and chemical defoamers can be applied alone or in combination to minimize the formation of foam and/or destroy any foam that is formed in the vessel.

An impeller in the liquid pool disperses aggregates of precipitated asphaltenes and enhances the release of solvent from the precipitated asphaltenes to the vapour phase. In addition, the stirring action submerges any floating asphaltene layer and prevents their re-agglomeration. Further, the stirring action keeps the solids in suspension, thereby avoiding plugging. Once a certain level of solvent removal has been achieved, the asphaltenes lose their tendency to float on the liquid pool and can be removed easily from the bottom of the vessel by conventional pumping means.

The process has been designed to operate in either single stage or multi-stage modes with the level of solvent removal at each stage governed by the temperature, pressure and residence time in each stage.

Additionally, an external vessel operating at a lower pressure than the primary solvent recovery vessel(s) may be employed to withdraw and collapse any accumulated foam layer via suitably located nozzles or other suitable means of withdrawing the accumulated foam layer.

DETAILED DESCRIPTION OF THE INVENTION:

The process for removing solvent from the underflow stream from a froth treatment solvent extraction process is depicted in Figure 1. The process depicted is a two-stage operation, which is the preferred configuration. During two-stage operation, the operating conditions of each of the solvent recovery vessels (temperature, pressure and degree of agitation of the liquid pool) are determined by the required solvent recoveries from each stage. Generally the bulk of the solvent (about 95%) will be recovered in the first stage, with the second stage ensuring enhanced recovery.

It should be noted that both solvent recovery vessels are identical and are able to function independently as a single stage, should the other vessel be unavailable. When functioning in single stage mode, the operating conditions of the given vessel needs to be adjusted to ensure that minimum solvent recovery targets are achieved.

Operation of the First Stage Solvent Recovery Unit (TSRU1)

The underflow stream [1] is the feed to the first stage solvent recovery unit (TSRU1) and is composed of a mixture of water, mineral solids (sand, silt/clays), precipitated asphaltenes, residual bitumen and solvent. The solvent is preferably, but not limited to, a C5/C6 paraffinic hydrocarbon mixture. This stream is heated to the desired operating temperature (e.g. 75°C to 90°C), before entering vessel via an inlet device. This is done either by direct steam injection or by indirect heating.

TSRU1 may be operated at various pressures. Operating slightly above atmospheric pressure is preferred (e.g. 150-200kPa). The heated stream [2] enters TSRU1 via an inlet device, which finely disperses the liquid components of the stream while at the same time minimising the formation of foam. This stream may be directed at an impingement

surface. The co-injection of an inert atomising gas such as nitrogen may be used to enhance this effect. As the heated stream [2] enters the vessel, the bulk of the solvent and some steam are released as vapour, while the remainder (primarily water, mineral solids, precipitated asphaltenes and residual bitumen) falls into the liquid pool at the bottom of the vessel, where final solvent removal is effected. A controlled volume of liquid is maintained in the liquid pool to provide sufficient residence time for the release of solvent from the solids. This, together with agitation, ensures that the required solvent recoveries are achieved.

Agitation of the liquid pool ensures that the solids and liquid are well mixed, particularly the less dense, solvent laden asphaltenes, which experience shear (reducing particle size) and are drawn under the liquid surface by the circulation flows generated by the agitator. Agitation via a mechanical stirrer or impeller is preferred. The location of the impeller in the liquid pool, the impeller configuration and rotational speed are selected so that optimal mixing is achieved. Alternate agitation means can be employed, such as a pump around circuit in which a variable speed pump is located outside the vessel in a piping arrangement which facilitates the pumping of slurry from the top of the liquid pool to the lower part of the liquid pool or visa -versa.

The bottoms from TSRU1 [3], which consists of de-solvented water, mineral solids, asphaltenes, residual bitumen and a small amount of residual solvent, are either pumped to the tailings pond (single stage operation – dashed line in Figure1) or preferably, to the second stage solvent recovery unit (TSRU2) (two-stage operation) for further solvent recovery.

The released solvent vapour passes up the vessel and into the overhead system. The vapour [4], which consists of solvent and water, flows through a condenser (1st Stage OVHD Condenser), where all of the vapour is condensed. The condensed stream [5] flows into an accumulator (1st Stage OVHD Accumulator) provided to separate out the water and solvent. The accumulator is designed for 3-phase separation (the three phases being water, solvent and non-condensable gases) with the production of solvent. The design allows for an overflow weir in the vessel. The aqueous phase will remain up-

stream of the weir and be drawn off [7]. Solvent will cascade over the weir and be drawn off [6]. This solvent is pumped to solvent storage for re-use in the froth treatment plant. Non-condensable gases from the second stage accumulator are vented into the Vapour Recovery Unit (VRU).

Oily water recovered from the 1st Stage OVHD Accumulator [7] is directed to a wash water flushing line included near the top of TSRU1. This can be used to supply water during operation to (a) control foam formation, should it occur, (b) wash any residue that may deposit on the walls of the vessel into the liquid and (c) dilute the bottom product in the event that it becomes too high in solids concentration and difficult to pump.

From time to time, depending on the underflow stream [1] composition, the formation of foam will occur during solvent removal. Generally this manifests itself as a foam layer accumulating on top of the liquid pool. Apart from those mentioned already, the following design features can be used to control foam:

- Steam can be injected directly into the foam layer above the liquid surface or into tubes located above the liquid surface.

- Foam abatement chemicals can be injected into the underflow stream and/or the vessel above the liquid level.

- For severe foaming episodes, a foam-breaking vessel can be used. In this case, excess foam is drawn through a foam-breaking device into the Foam Breaking Vessel [14]. The Foam Breaking Vessel is operated at a pressure lower than TSRU1, about 100-150kPa. Wash water and foam abatement chemicals may also be added to the vessel, which is agitated to avoid plugging. The collapsed foam residue [15] is pumped back to TSRU1 (during single-stage operation) or TSRU2 (during two-stage operation). If TSRU2 is used in a single stage operation (bypassing TSRU1) then the Foam Breaking Vessel is operated at a pressure lower than TSRU2.

Operation of the Second Stage Solvent Recovery Unit (TSRU2)

In this configuration, the bottoms stream [3] from TSRU1 is fed to the second solvent recovery vessel (TSRU2). TSRU2 is mechanically identical to TSRU1 and contains all of the features described for TSRU1.

The operating conditions in TSRU2 will generally be different to those in TSRU1. Typically, the pressure will be lower (e.g. 50 to 70kPa) and the temperature will be about 50°C to 70°C, depending on the final solvent recovery target. Under these conditions, as the stream enters the vessel via the inlet device, further solvent is released into the vapour space, with the rest of the stream reporting to the liquid pool where a controlled volume is maintained. Agitation of the liquid pool ensures that the solids and liquid are well mixed. The bottoms from TSRU2 [8], which now consists of further de-solvented water, mineral solids and asphaltenes are pumped to the tailings pond.

The released solvent vapour passes up the vessel and into the overhead system. The vapour [9], which consists of solvent and water, flows through a condenser (2nd Stage OVHD Condenser), where all of the vapour is condensed. The condensed stream [10] flows into an accumulator (2nd Stage OVHD Accumulator) provided to separate out the water and solvent. The aqueous phase will remain up-stream of the weir and be drawn off [12]. This oily water is directed to a wash water flushing line included near the top of TSRU2. Solvent will be drawn off [11] and pumped to solvent storage for re-use in the froth treatment plant. Non-condensable gases from the second stage accumulator are vented into the Vapour Recovery Unit (VRU).

The same design features as those described for TSRU1 have been put in place to control foam formation in TSRU2.

CLAIMS

1.   A process for treating an underflow stream, containing water, solvent, asphaltenes and solids, from the last separation step in a paraffinic solvent process for separating bitumen from an oil sands froth, wherein

   a) the stream is introduced to a solvent recovery vessel that is substantially free of internals wherein the temperature and pressure are such that the solvent is normally a vapour,

   b) a pool of liquid and solids is maintained in the lower part of the vessel at a controlled level for sufficient time to allow the solvent to vapourize,

   c) the pool is agitated to a level of agitation where the asphaltenes are dispersed, submerged and re-agglomeration of asphaltenes is inhibited and the solids are maintained in suspension,

   d) the solvent is recovered as an overhead vapour stream, and

   e) the solvent depleted remainder of the stream is removed from the bottom of the vessel as a liquid slurry.

2. The process of claim 1, wherein the pool is agitated with a mechanical impeller.

3. The process of claim 2, wherein the impeller configuration, location in the liquid pool, and rotational speed are selected to promote that floating solvent laden asphaltenes are drawn under the liquid surface and to prevent re-agglomeration of the asphaltenes and to promote asphaltene particle size reduction.

4. The process of any one of claims 1-3 wherein the stream is introduced to the vessel above the liquid level of the pool.

5. The process of any one of claims 1-4, wherein the stream is introduced to the vessel via an inlet device which induces a pressure drop sufficient to atomise the liquid components of the feed to the vessel while at the same time minimising the formation of foam.

6. The process of any one of claims 1- 5, wherein the stream is heated before the stream is introduced to the vessel by direct mixing with injected steam to minimise the formation of foam.

7. The process of any one of claims 1-6, wherein an inert atomising gas such as nitrogen is mixed with the stream before the stream is introduced to the vessel to minimise the formation of foam.

8. The process of any one of claims 1-7, wherein the stream, as it is introduced to the vessel, is directed to an impingement surface to minimise the formation of foam.

9. The process of any one of claims 1-8, wherein means are employed to reduce the amount of foam that is formed above the liquid level in the vessel.

10. The process of claim 9, wherein steam is injected directly into the vessel above the liquid level for the purpose of maintaining temperature and destroying foam.

11. The process of claim 10, wherein steam is circulated in steam coils located in the vessel above the liquid level for the purpose of maintaining temperature and destroying foam.

12. The process of claim 9, wherein water is sprayed into the vessel above the liquid level for the purpose of destroying foam.

13. The process of claim 9, wherein foam abatement chemicals are injected into the stream and/or the vessel above the liquid level for the purpose of destroying foam.

14. The process of any one of claims 1-13, wherein in addition to said solvent recovery vessel a second stage solvent recovery vessel is employed which is connected in series with the first stage solvent recovery vessel.

15. The process of claim 14, wherein the liquid slurry stream from the bottom of the first stage vessel is fed to the second stage solvent recovery vessel.

16. The process of claims 14 or 15, wherein the second stage solvent recovery vessel is substantially free of internals and

a)   a pressure and a temperature are maintained in the second stage vessel such that the solvent is normally a vapour,

b)   a pool of liquid and solids is maintained in the lower part of the second stage vessel at a controlled level for sufficient time to allow the solvent to vapourize,

c)   the pool in the second stage vessel is agitated to a level of agitation where the asphaltenes are dispersed, submerged and re-agglomeration of asphaltenes is inhibited and the solids are maintained in suspension,

d)   the solvent is recovered from the second stage vessel as an overhead vapour stream, and

e)   the solvent depleted remainder of the stream is removed from the bottom of the second stage vessel as a liquid slurry.

17. The process of any one of claims 14-16 , wherein the operating conditions such as temperature, pressure and degree of agitation of the first and second stage solvent recovery vessels are controlled according to the required solvent recoveries from each stage.

18. The method of any one of claims 14-17, wherein the second stage solvent recovery vessel is operated a reduced pressure relative to the first solvent recovery vessel to reduce any amount of foam that may still be associated with the bottom stream from the first stage solvent recovery vessel .

19. The method of any one of claims 14-18 , wherein each of the first and second stage solvent recovery vessels has a solvent recovery capacity which is sufficient to operate as a single solvent recovery vessel , thereby ensuring continuity of the solvent recovery process should one of the solvent recovery vessels be unavailable.

20. The process of any one of claims 14-19, wherein a foam-breaking vessel is located between the first and second stage vessels to collect any excess foam generated during severe foaming episodes from either the first or second solvent recovery vessels.

21. The process of claim 20, wherein in the foam-breaking vessel the foam is broken via mechanical shear and/or the addition of foam abatement chemicals or other means.

22. The process of claim 20 or 21, wherein the pressure in the foam-breaking vessel is lower than the pressures in the first and second stage solvent recovery vessels.
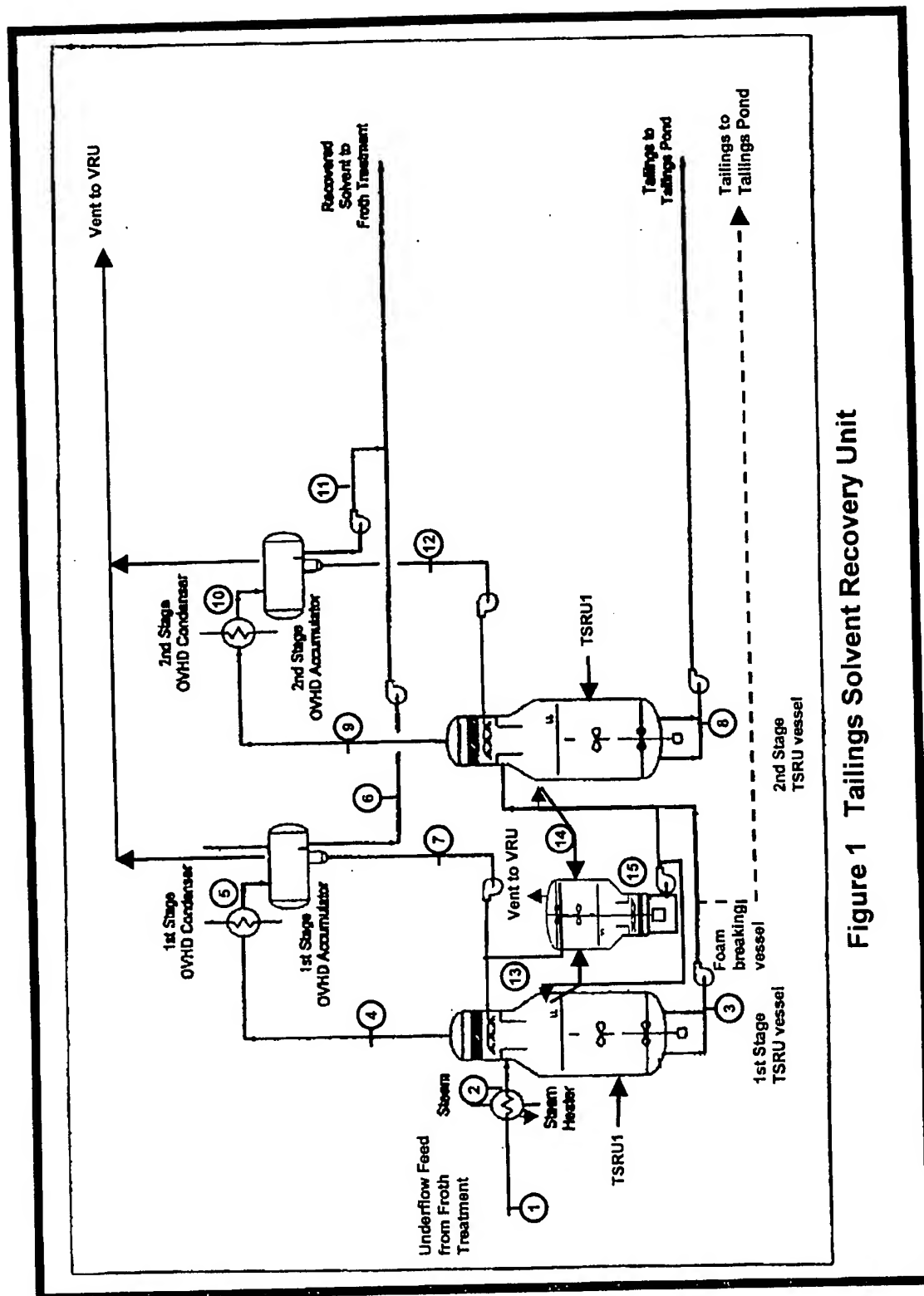
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Figure 1   Tailings Solvent Recovery Unit